EP311 Electronics I 2005 Term I
Prof. M. P. Bradley
FINAL EXAM 10 DEC 2005 2 p.m.

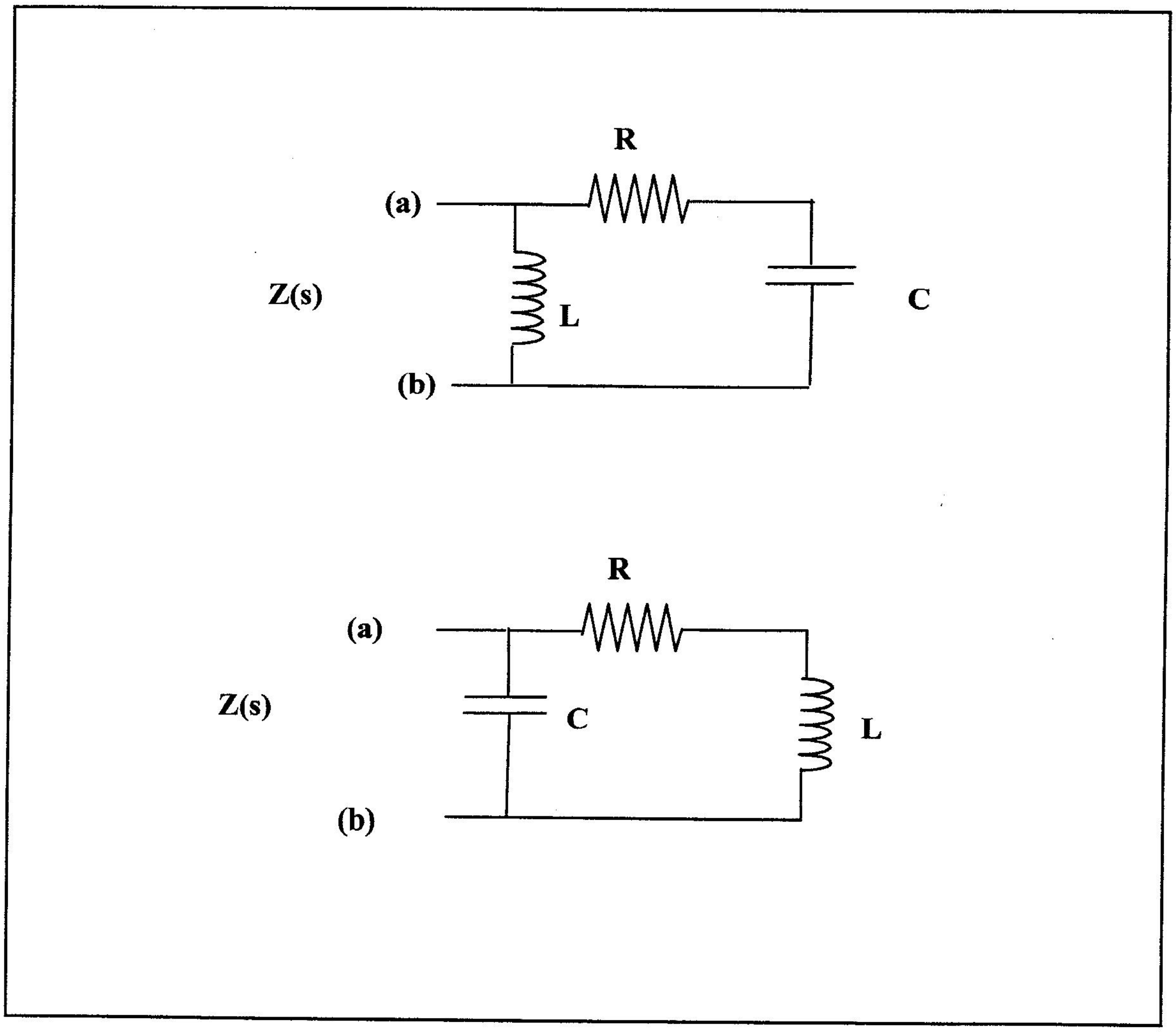
EP311 Fall Term 2005
Final Exam (50% of total course grade)

6 problems, all equal weight

Problem 1: Generalized Impedances

Write the generalized impedances **Z(s)** presented between the terminals (a) and (b) of the 2 circuits shown below. Arrange the expression for **Z(s)** such that you have polynomials in increasing powers of **s** in both the numerator and denominator.

Sketch on the s-plane the poles and zeros in each case. Note that you may assume that component values have been chosen such that $\left(\frac{R}{2L}\right)^{2} < \frac{1}{LC}$



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Problem 2: Semiconductor Physics

The portion of the periodic table most important for semiconductor work is reproduced below

Group III	Group IV	Group V
Boron (B) Z=5	Carbon (C) Z=6	Nitrogen (N)Z=7
Aluminum (Al) Z=13	Silicon (Si) Z=14	Phosphorus (P) Z=15
Gallium (Ga) Z=31	Germanium (Ge) Z=32	Arsenic (As) Z=33
Indium (In) Z=49	Tin (Sn) Z=50	Antimony (Sb) Z=51

(a) A silicon sample is doped with Boron such that N(B)/N(Si) = 10^{-6}. What type of doping is this ? What is the electrical conductivity ?
(b) The same sample is now doped with Arsenic to the ~~same concentration,~~ i.e. N(As)/N(Si) = 5×10^{-7} . What type of doping does this produce ? What is the conductivity now ?
(c) Compare the conductivities of the two doped samples. Which is higher, and why ?

Additional Useful Information
Physical Parameters for Silicon:
Atomic concentration
$N(Si) = 5.0 \times 10^{22}\ cm^{-3}$

$n_i = 1.5 \times 10^{10}\ cm^{-3}$
$\mu_e = 1350\ cm^2/V.s$
$\mu_h = 480\ cm^2/V.s$

Recall also $\sigma = e(n_e \mu_e + n_h \mu_h)$ {e = electron charge = 1.6×10^{-19} Coulomb}

(b) At room temperature (assume 25 degrees C) the current in a silicon diode is measured to be 200 mA at a forward bias voltage of 0.7 Volt. What is the reverse leakage current for this diode ? What current would flow at a forward bias of 0.6 Volt ?

Ref: Shockley equation $I = I_0 [e^{(eV/\eta kT)} - 1]$ ($\eta \approx 1$ and $k = 1.38 \times 10^{-23}$ J/K)

Problem 3: Bipolar Junction Transistor (BJT)

(a) In the circuit given below the Bipolar Junction Transistor Q1 has the following parameters at room temperature (assume 25 °C):
β=100
I_{CBO}=100 pA.

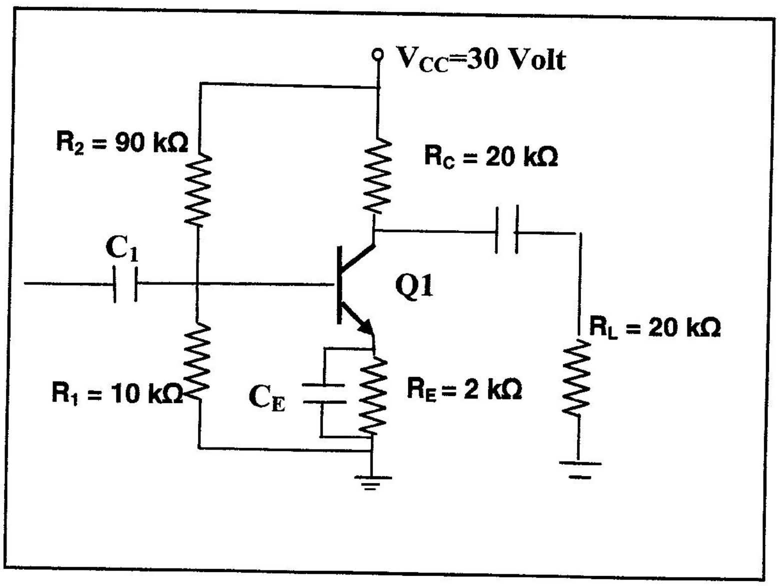
Given the following changes in parameters as a function of temperature:
ΔV_{BE} = -2.5 mV/°C
I_{CBO} doubles for every 10 °C rise in temperature
β increases from 100 to 200 when the temperature increases by 50 °C

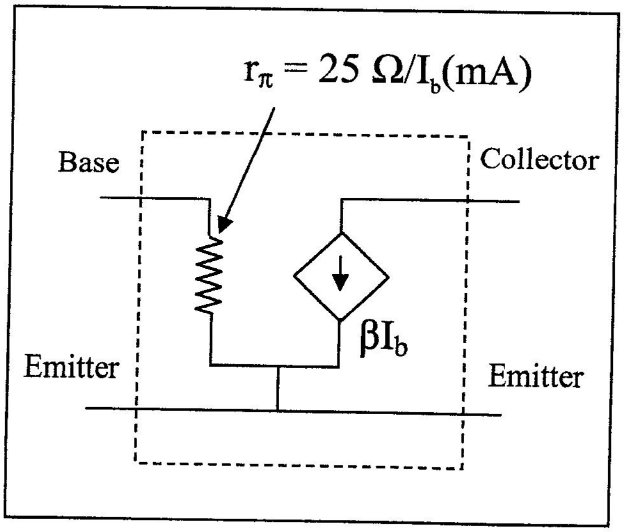
Use the standard BJT bias stability equation (given) to calculate the change in collector current due to a 50 °C rise in temperature: $I_C = \dfrac{V_{BB} - V_{BE} + (1+\frac{1}{\beta})I_{CBO}(R_B + R_E)}{R_E + \dfrac{R_B + R_E}{\beta}}$

(Recall that R_B is the parallel combination of the base bias resistors R_1 and R_2, i.e. $R_B = R_1 // R_2$)

(b) If the lowest desired frequency of operation is 2 kHz, choose capacitors C_1, C_2, and C_E

(c) Draw the AC equivalent circuit assuming the capacitors have been chosen correctly and that V_{CC} is an AC ground. Then replace the transistor by the r_π - β model of the transistor shown in the figure and calculate the voltage gain (Remember the emitter is AC-shorted to ground if the C_E capacitor is properly chosen)





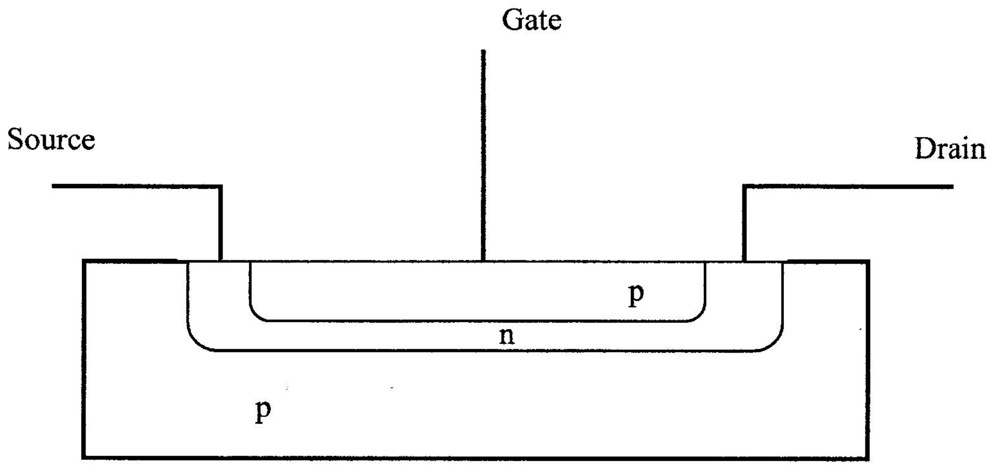
Problem 4: JFET Circuit

(a) Explain qualitatively how the following n-channel JFET works. Sketch a circuit showing the proper biasing for this device

(b) What is the circuit symbol for this device, and why is it drawn the way it is ?

(c) Why do we never forward bias the gate channel junction ?

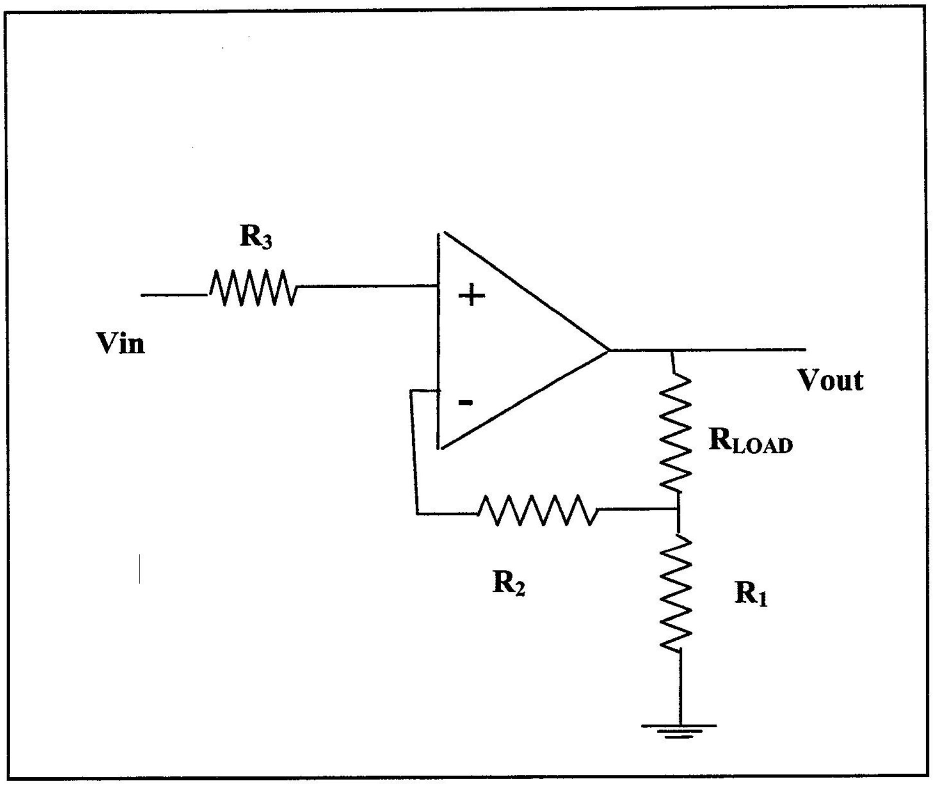
(d) What is the chief advantage of a JFET over a BJT ?



Problem 5: Op-amp DC Current Source

Use the op-amp current and voltage rules (OACR and OAVR) to find the expression for the current through the load resistor R_{LOAD} in terms of the input voltage **Vin** for the circuit below.

Describe the function of this op-amp circuit in words.



Problem 6: Op-amp AC Circuit – Effective Inductance using Capacitors & Feedback

(a) Derive the relationship between $V_{in}(\omega)$ and $I_{in}(\omega)$ for the following op-amp circuit by using the op-amp current and voltage rules (OACR, OAVR).

(b) What is the effective inductance of this circuit ?

(c)Why is this not a true inductor simulator ?